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14. ABSTRACT

Due to difficulties and uncertainties in accurately representing the bubbly flow around a ship in a laboratory facility, there is a need for full-scale (or near full-scale) measurements of bubbly flows generated around surface ships. These needs are parallel to components of ONR's ship hydromechnics program (Free-Surface Phenomena and Two-Phase Flows) which "…seeks to understand the physical mechanisms underlying interactions of two-phase water flow around ships and in their wakes with the air/sea boundary, and to incorporate that information in a computational fluid dynamics flow solver."

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FINAL REPORT

Contract Information

Contract Number	N00014-04-1-0702
Title of Research	DURIP: EQUIPMENT FOR NAVAL HYDRODYNAMIC STUDIES
Principal Investigator	Eric Terrill
Co-Principal Investigator	Ken Melville
Organization	Scripps Institution of Oceanography

Technical Section

Technical Objectives

Due to difficulties and uncertainties in accurately representing the bubbly flow around a ship in a laboratory facility, there is a need for full-scale (or near full-scale) measurements of bubbly flows generated around surface ships. These needs are parallel to components of ONR's ship hydromechnics program (Free-Surface Phenomena and Two-Phase Flows) which "…seeks to understand the physical mechanisms underlying interactions of two-phase water flow around ships and in their wakes with the air/sea boundary, and to incorporate that information in a computational fluid dynamics flow solver." A recent NRC report on Naval Hydromechanics (REF) concludes that the achievement of this goal will require at-sea measurements around full-scale (or almost full scale) ships. The equipment acquired under this DURIP grant allowed the purchase, testing, and refinement of an acoustic volumetric imaging device which allows estimation of the spatial distribution of bubble populations at O(1) resolution across significant volumes of several tens of cubic meters (Terrill). The original proposal also included a broad suite of visible and infrared imaging equipment (Melville), but due to lack of funding from the program, the sponsor cut this component.

Description of Equipment and Usage.

The Echoscope II (ES II) is a real-time 3D acoustic imaging sonar. This project experienced a 2 year delay in delivery of the equipment as a result of the original Norwegian Company (Omnitech) being purchased by a UK Company (CodaOctopus), which later incorporated in the U.S. During this transition time period, several modifications were made to the sonar design, which required iteration with Scripps to ensure the final delivery met our stated requirements to measure acoustic backscatter.

As a result of delays, the equipment was used expressly for the ONR Ship Hydrodynamics program several years later during a full-scale field experiment in Panama City, Florida between April 20 – 23, 2009 to capture underwater acoustic images of the ***R/V Athena's*** bubbly wake. The Echoscope has a 375 kHz frequency transducer, a 128 x 128 beam array, an effective output rate of 5-10 Hz, and an adjustable range resolution of 4 – 100 cm. The unit has been calibrated to output target strength.

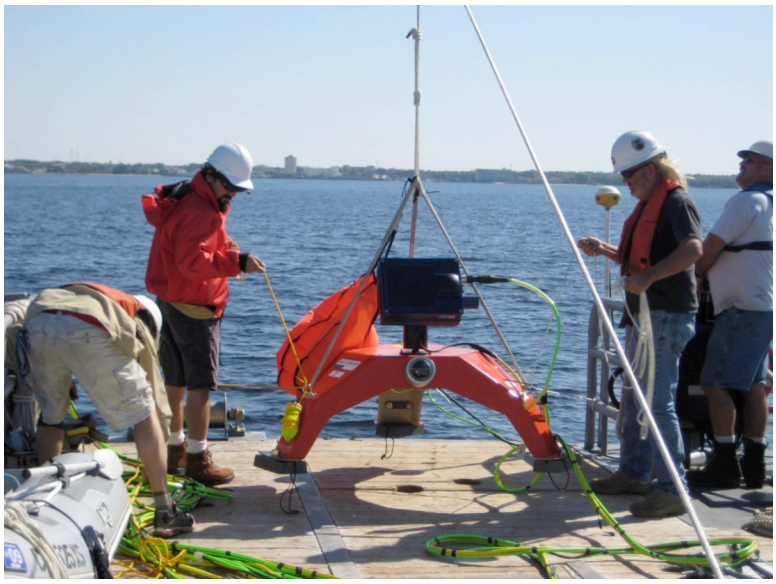

Fig 1. The Echoscope II was mounted on a tripod. The unit is being lifted from the PSC-8 vessel in preparation for deployment onto the seafloor.

The field experiment first took place in St. Andrew's Bay during April 20 – 21 due to high winds (20-25 kts) from a recent storm. On April 22 – 23, the experiment was moved to ~40 miles in the Gulf. The Echoscope was mounted to a tripod, which was lowered each day to the seafloor, and the unit was angled 40-50° upwards to measure the bubble field as the ***R/V Athena*** transited overhead. The ***Athena*** followed a southwesterly-northeasterly track and ran at speeds of 7.0, 8.0, 9.0, 10.5, 11.5, and 12.0 kts.

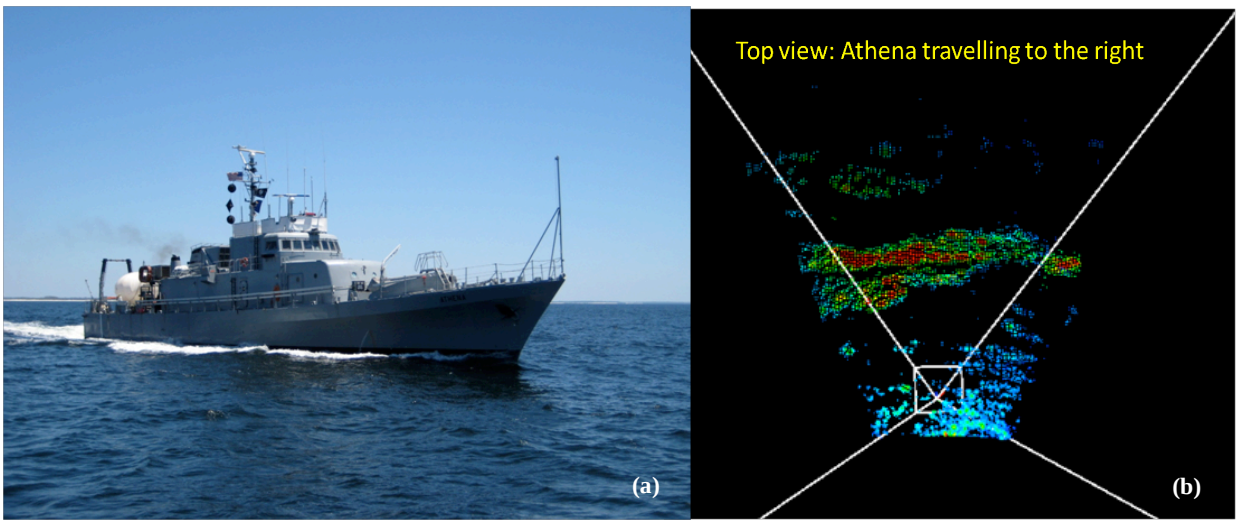

Fig 2. (a) View of the R/V Athena during a run. (b) Real-time returns from the ES II were visible via the provided software. Here the wake created by the bow and side hull is shown.

The appearance of the ***Athena's*** wake in the Echoscope's field of view was easily observed using Echoscope's real-time software. A bright V-shaped signal (or half of a V) initially appeared when the Athena approached. The bubble cloud was observed to linger between 0-2 m depth, and some bubbles were found as deep as 4 m. The bubble field persisted for approximately 10 minutes, after which the Athena prepared for another run through the measurement field. Using the real-time software, we were also able to observe a current advecting the bubble cloud on several of the test days.

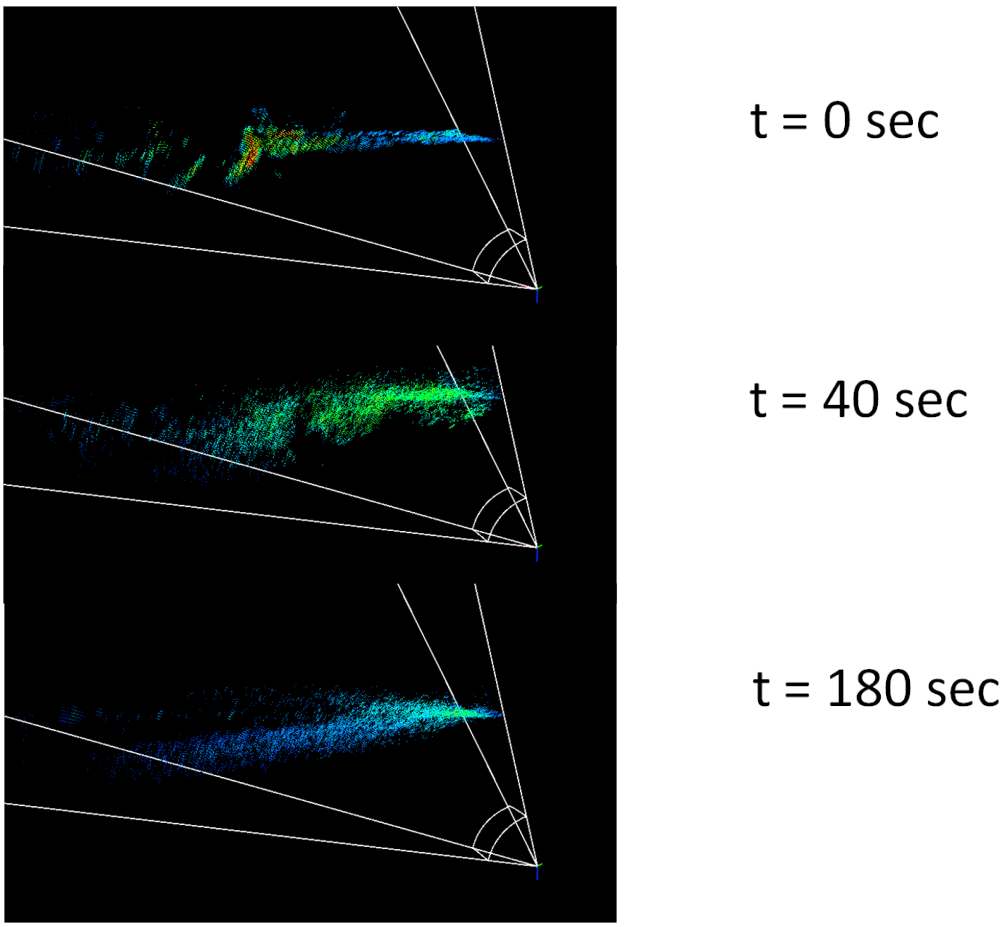

Fig 3. Sample images of the maximum return field captured by the Echoscope at 0, 40, and 180 seconds after the ***Athena*** came into the Echoscope's field-of-view.

Conclusion

Funding of the DURIP Instrumentation award has allowed us to make novel measurements of the bubbly wake of a full-scale vessel at scales previously not resolved. The equipment is now functioning as originally planned, and data from the system will be used in ongoing research programs sponsored by Dr. Patrick Purtell of ONR CODE 33.